Prepared for:

ALBERTA ENVIRONMENT

EARTH SCIENCES DIVISION - SOILS BRANCH

HYDROGEOLOGY OF THE CONSORT SITE

SUMMARY REPORT

A Site Evaluation for the

Proposed

SPECIAL WASTE MANAGEMENT FACILITY

Prepared by:

C.E. Moell, P.Geol.
A.M. Hingston, P.Geol.

C.E. MOELL & ASSOCIATES LTD.

TABLE OF CONTENTS

SECTION ONE - INTRODUCTION

1.1 Introduction 1
1.2 Location and Access 1

SECTION TWO - LAND SURFACE DESCRIPTION AND USE

2.1 Topography and Drainage 3
2.2 Land Use 3

SECTION THREE - GEOLOGY

3.1 Introduction 5
3.2 Surficial Geology 5
3.3 Bedrock (Cretaceous) Geology 9
3.4 Bedrock Topography 9

SECTION FOUR - GROUNDWATER

4.1 Introduction 11
4.2 Watertable Depth and Configuration 11
4.3 Hydraulic Conductivity of Near-Surface Sediments 12
4.4 Groundwater Velocity 15
4.5 Vertical Component of Groundwater Flow 16
4.6 Groundwater Resources 17
4.7 Potential for Groundwater Contamination 18

SECTION FIVE - SUMMARY AND CONCLUSIONS 20

SECTION SIX - RECOMMENDATIONS 22

LIST OF TABLES

Table 3.1: Particle Size Analyses of Geologic Materials . . 7
Table 4.1: Hydraulic Conductivity of Geologic Materials . . 13

LIST OF FIGURES

Figure 1.1: Location and Access Plan 2
Figure 2.1: Land Use Plan 4
Figure 3.1: Test Hole Location Plan 6
Figure 3.2: Particle Size Distribution 8
Figure 3.3: Textural Variation with Depth -
Test Holes 13 and 26 10

SECTION ONE

INTRODUCTION

1.1 Introduction

The SE 17-34-6-W4, herein referred to as the Consort Site, was selected through a constraint mapping process as a potential candidate site for the location of a special waste management facility. Favourable characteristics identified during constraint mapping include a fine-textured glacial till mantle overlying the Bearpaw Formation. The Bearpaw is a marine-origin sedimentary formation known for its relatively thick shale sequences and lack of potable groundwater. A detailed investigation was conducted on the site in order to confirm favourable hydrogeologic conditions, and to identify potential constraints to development. This report represents a summary of the final hydrogeologic report prepared for the site; the final report contains a greater level of detail for the Consort Site and surrounding areas. Hydrogeologic maps at a scale of 1:2000 are contained in the final report, and hydrogeologic details are appended.

1.2 Location and Access

The Consort Site is located 12.8 road km southwest of Consort, Alberta. Access is 7.2 km south from Consort via Secondary Road 886 (oiled), 3.2 km west by gravel road, and 2.4 km south along an unimproved road allowance (Figure 1.1). The eastern boundary of the Consort Site is unfenced and access to the property is currently available along most of the eastern boundary.

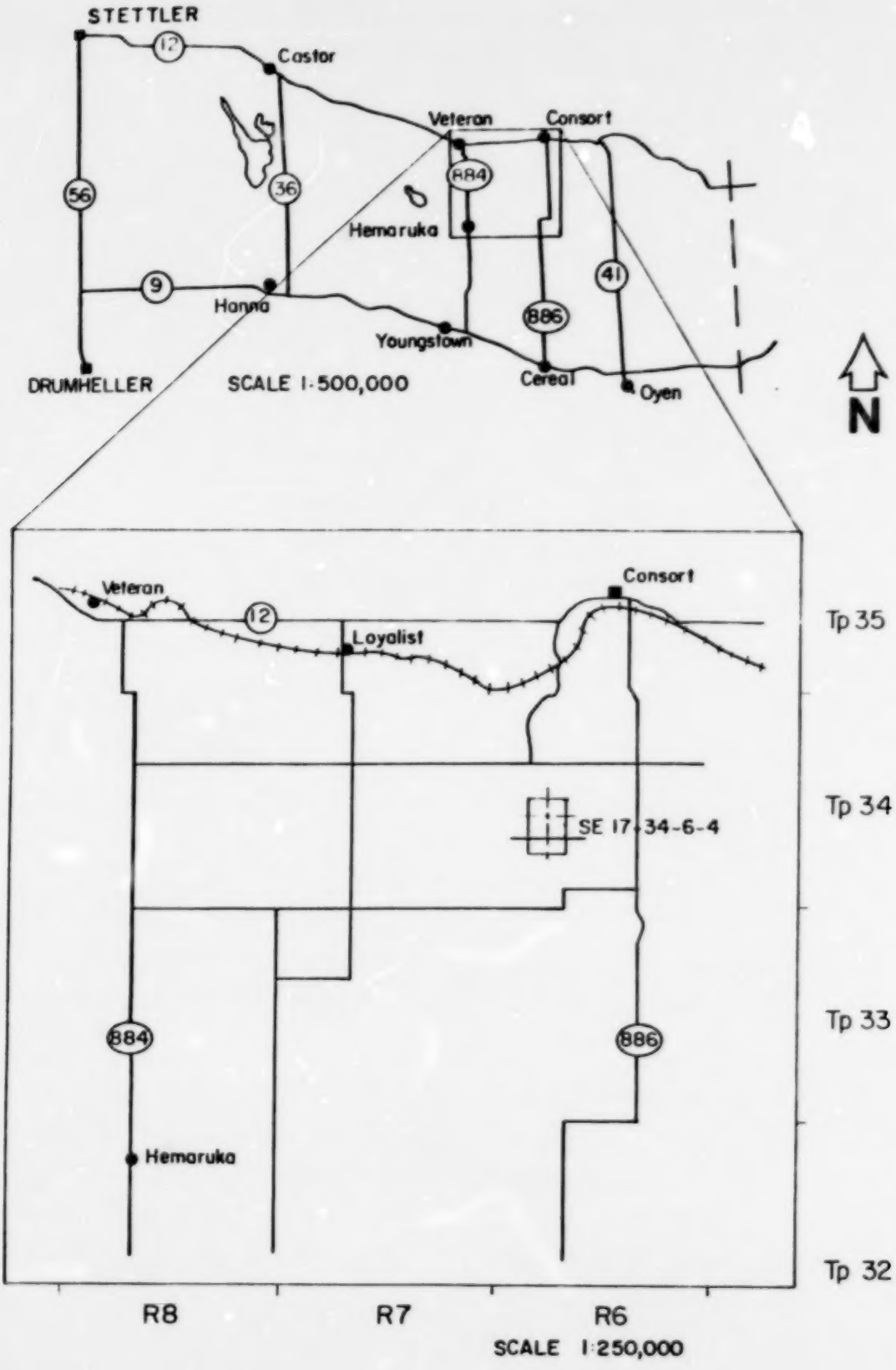


Figure 1.1 Location and Access Plan

SECTION TWO

LAND SURFACE DESCRIPTION AND USE

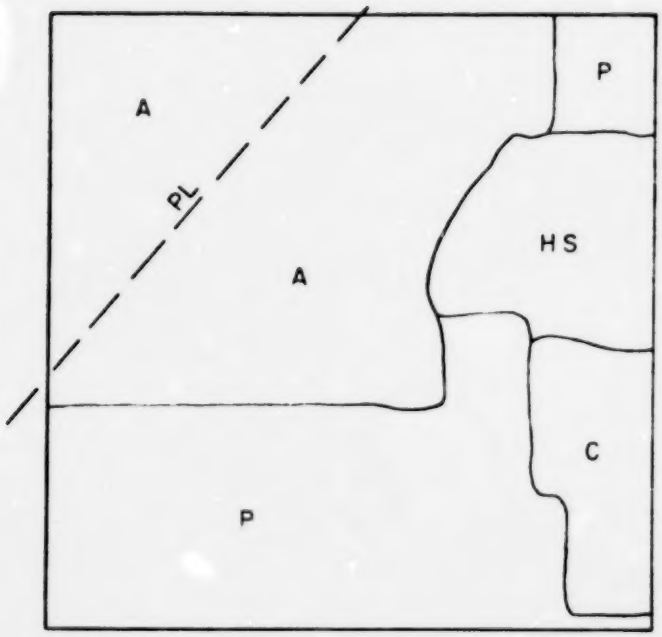
2.1 Topography and Drainage

The Consort Site is located in a regional topographic high and, as such, is well drained. Geodetic elevations on site range from 783 to 797 metres, for a total relief of 14 metres. A level-topped topographic high occupies the centre of the quarter, and the land surface drops gently north, east and south. A sharp topographic break trends through the northwest part of the site, resulting in a sharp westward drop into a northeast-southwest valley trending through adjacent quarters. Most of the property is well-drained; there are no surface drainage courses within the quarter and the few scattered sloughs are dry most of the time.

2.2 Land Use

The Consort Site is currently used for forage (74 acres) and cereal crop (12 acres) production, and fall pasture. An abandoned farmstead occupies 17 acres and the remaining land surface (57 acres) appears to be unbroken native prairie. Road allowances bound the east (unimproved) and south (abandoned) sides of the property. Barbed wire is stretched along the south boundary only. A natural gas pipeline trends southwest-northeast across the northwest corner of the quarter. The line is not marked on property boundaries, is not visible on the ground in cultivated areas, and is only faintly visible on new aerial photography. The pipeline is approximately located in Figure 2.1; an accurate plan of the right-of-way is available through the Calgary land titles office.

Figure 2.1 LAND USE PLAN



Scale 1:9240

Legend

	Acres
A - Alfalfa Crop	74
C - Cereal Crop	12
P - Prairie	57
HS - Homestead (abandoned)	17
PL - pipeline	

SECTION THREE

GEOLOGY

3.1 Introduction

The geology of the Consort Site was investigated by drilling 25 dry auger holes on a 200 metre grid as indicated in Figure 3.1. Most of the auger holes were restricted to an 18 metre depth; two rotary holes were drilled to determine the geology between the 18 and 90 metre depth. As indicated in Figure 3.1, test holes were also drilled on adjacent quarters, primarily to determine if adverse geologic conditions were in proximity to SE 17. The geology of the six quarter section study area is contained in the final report.

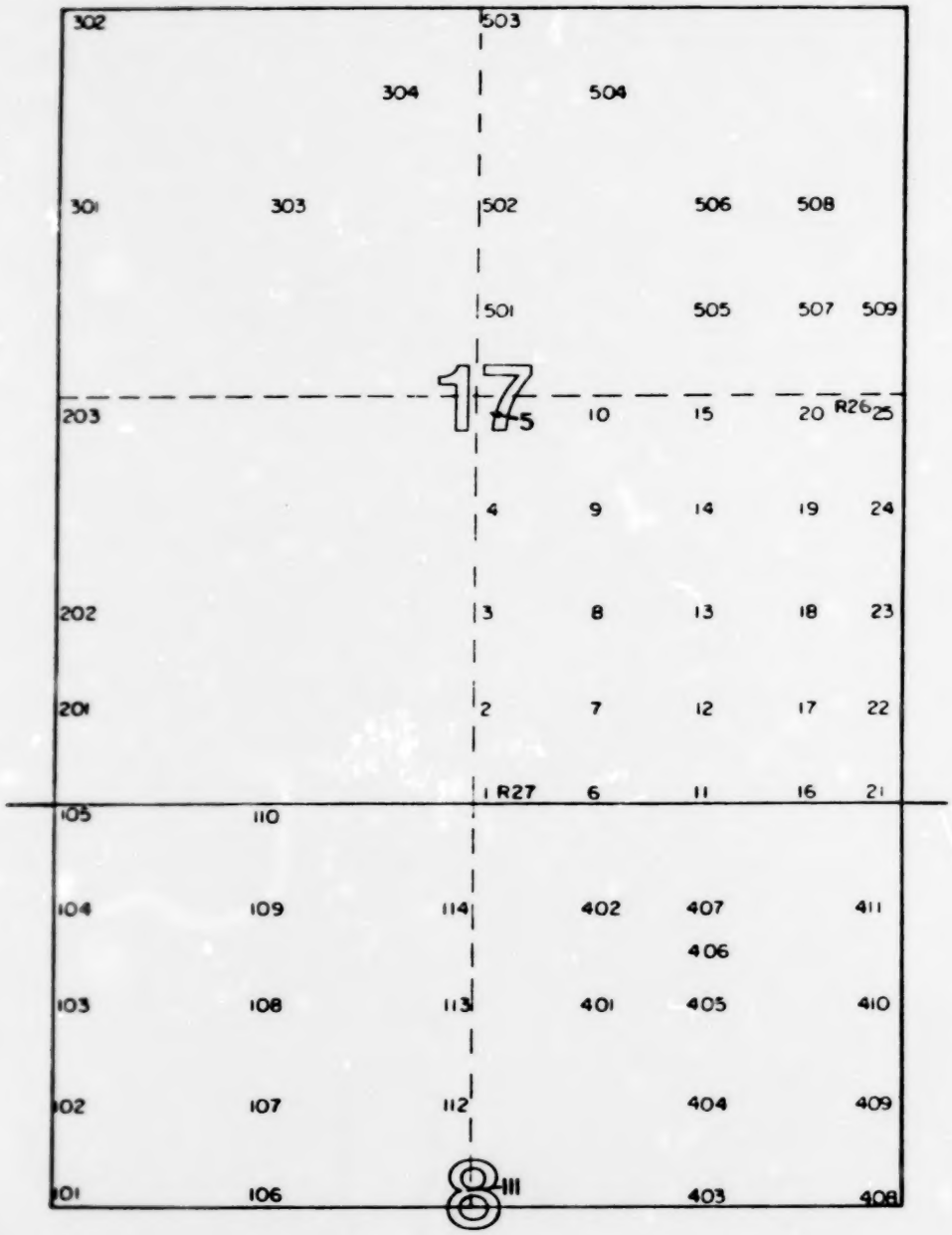
3.2 Surficial Geology

Surficial materials mantling the Consort Site consist primarily of glacial till with small pockets of lacustrine deposits in low-lying areas. The till is predominantly clay-loam textured, and ranges in thickness from 6.1 to 42.1 metres. Isolated occurrences of loam and sandy loam-textured till are present within the drift thickness, but these are rare. Glaciofluvial sands or sands and gravels are present at isolated locations beneath both eastern and western boundaries of the site. Till textures are indicated in Table 3.1, and graphically displayed in Figure 3.2.

The glacial drift cover is weathered, as indicated by secondary oxide mineralization, to depths ranging from 4.7 to 12.8 metres. Weathering effects have penetrated the drift cover and extend into the underlying bedrock near the northeast and southwest corners of the site.

Figure 3.1 TEST HOLE LOCATION PLAN

CONSORT STUDY AREA



NOTES

1. Rotary holes denoted by R
2. Drill hole grid is 200m (approximate)
3. Map area encompasses N 1/2 8 and Section 17-34-6-W4

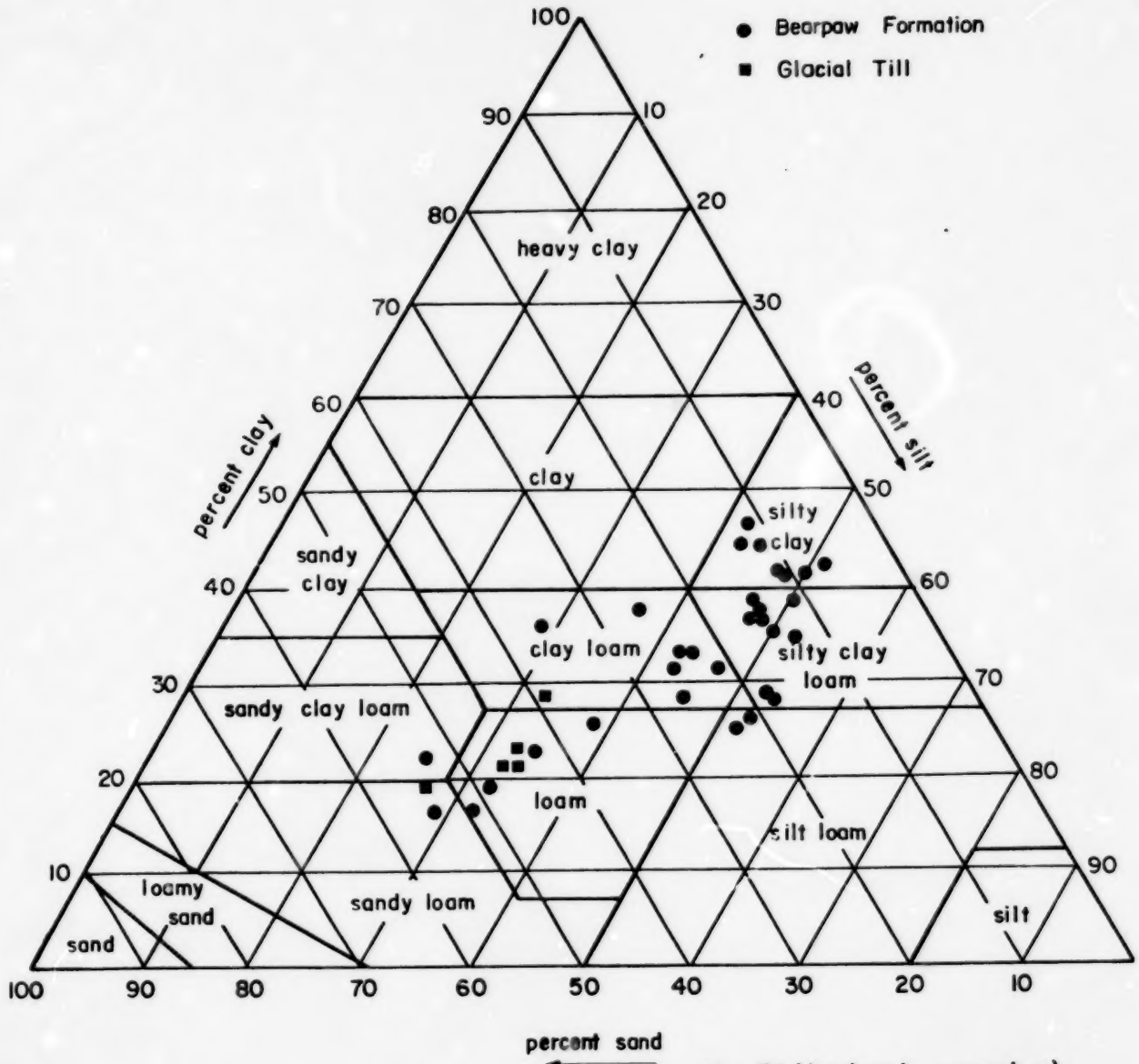
Table 3.1: Particle Size Analyses of Geologic Materials

Sample No.	Depth (m)	Material	Texture
H13- 1	1.5	Till	CL
2	3.0	Till	L
3	4.5	Till	L
4	6.1	Till	L
5	7.6	Till, Sandy	SL
6	9.1	Shale	SiCL
7	10.6	Shale	SiL
8	12.2	Shale	CL
9	13.7	Shale	SiCL
10	15.2	Shale	SiCL
11	16.7	Shale	SiC
12	18.2	Shale	SiC
H26- 1	19.0	Shale	SiC
2	22.0	Sandstone	SCL
3	26.0	Sandstone	SL
4	30.0	Sandstone	L
5	33.0	Sandstone	L
6	36.0	Sandstone	L
7	37.0	Shale	CL
8	41.0	Shale	SiCL
9	44.0	Shale	SiCL
10	47.0	Shale	SiCL
11	50.0	Shale	SiCL
12	54.0	Shale	CL
13	57.0	Shale	SiC
14	60.0	Shale	CL
15	63.0	Sandstone	L
16	66.0	Shale	SiL
17	69.0	Shale	SiCL
18	72.0	Shale	SiCL
19	75.0	Shale	SiC
20	78.0	Shale	SiC
21	81.0	Shale	SiC
22	84.0	Shale, Sandy	CL
23	87.0	Sandstone	CL
24	90.0	Shale, Sandy	CL

Legend:

SL - Sandy Loam
SCL - Sandy Clay Loam
L - Loam
CL - Clay Loam
SiL - Silt Loam
SCL - Silty Clay Loam
SiC - Silty Clay

Figure 3.2 Particle size distribution



N = 31 (bedrock samples)

Field	% samples in field
SCL	3.2
SL	3.2
L	12.9
CL	22.9
SiL	6.5
SiCL	29.0
SiC	22.6

3.3 Bedrock (Cretaceous) Geology

The Cretaceous sedimentary sequence beneath the Consort Site consists of interbedded silty shales and argillaceous sandstones. The subcrop materials consist exclusively of shale except in the northwest corner where preglacial erosion has exposed a sandstone unit which lies stratigraphically beneath the shale. The sandstone unit, depicted in Figure 3.3, is everywhere overlain by a till or till plus shale thickness of at least 22 metres.

Except for thin indurated sandstone and concretionary horizons, the bedrock sequence to a depth of 90 metres is unconsolidated. The shales are silt loam to silty clay loam textured, and sandstones are loam to clay-loam textured (Table 3.1 and Figure 3.2). Based on the fossiliferous nature of the shales, and glauconitic mineralogy of the sandstones, the sedimentary sequence to 90 metres beneath the Consort Site is considered part of the marine-origin Bearpaw Formation.

3.4 Bedrock Topography

Relief on the bedrock surface is considerably greater than the topographic relief. A bedrock high trends north-south through the central part of the site and falls gently east and south. The bedrock surface drops sharply westward along the western part of the site, into a buried preglacial valley. Total relief on the bedrock surface within the confines of SE 17 is 49 metres.

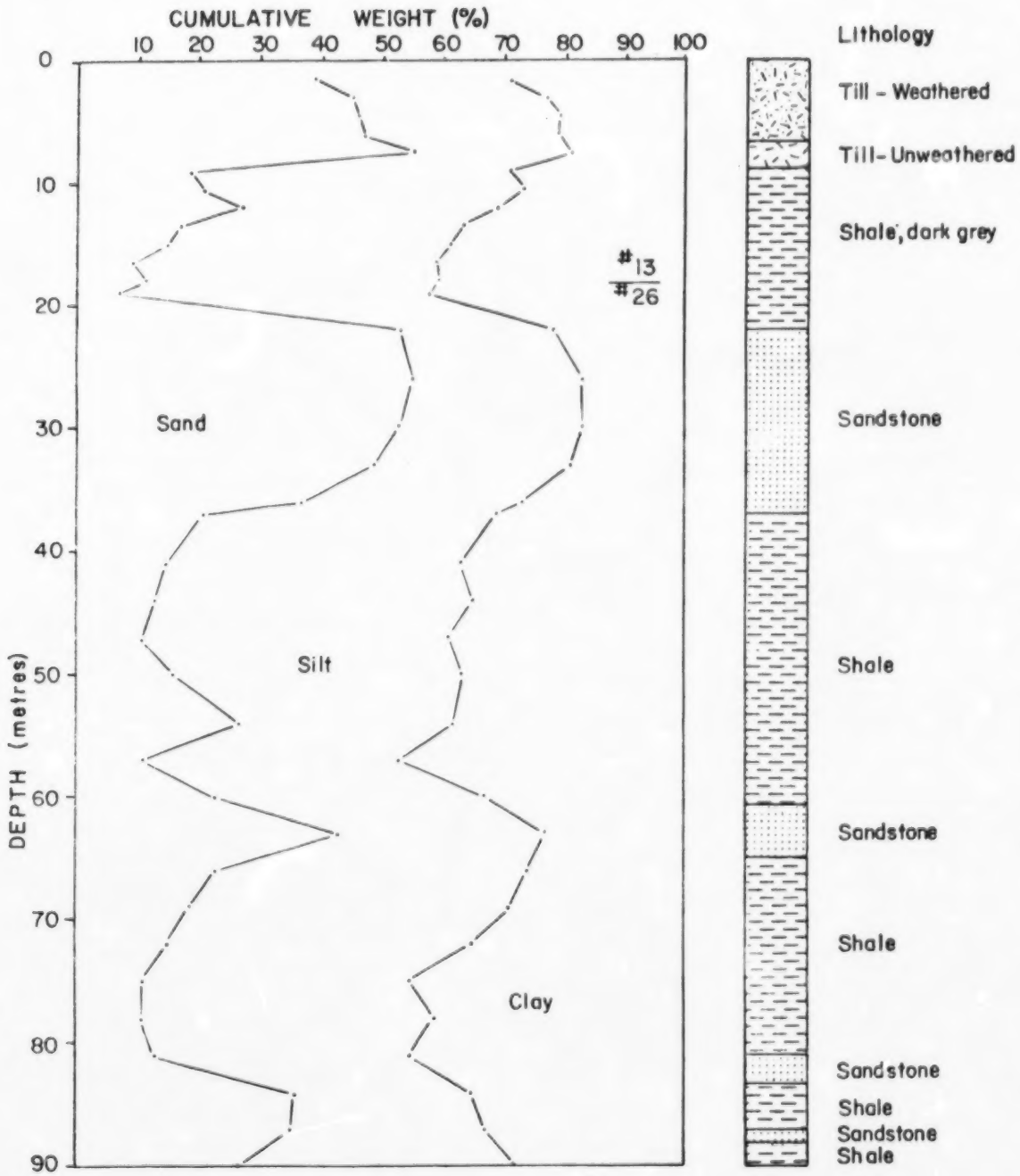


Figure-3.3 TEXTURAL VARIATION WITH DEPTH

TEST HOLES 13 (0-18m) and 26 (19-90m)

SECTION FOUR

GROUNDWATER

4.1 Introduction

Groundwater conditions including watertable depth, configuration and potential groundwater velocities were determined by monitoring a network of piezometers. Twenty-five piezometer nests were installed on a 200 metre grid system, each nest consisting of either three or four piezometers for a total of 77. Piezometric levels and hydraulic conductivity determinations were made at approximate depths of 6, 12, and 18 metres.

4.2 Watertable Depth and Configuration

The watertable as defined herein is represented by the uppermost level of groundwater-saturated sediments in the subsurface. As indicated in Section Three, there are no potential aquifers in the drift-bedrock sequence to a depth of 22 metres but local precipitation events will allow formation of a saturation zone perched within otherwise impermeable sediments.

The watertable lies at depths generally from five to eight metres below surface, being deepest beneath topographically higher areas and shallowest in low areas and adjacent to sloughs. As is characteristic in most drift-covered areas in the province, the watertable configuration is a reflection of surface topography. An equipotential or watertable contour map indicates radial flow along lines originating in the central (topographically highest) part of the Consort Site, and directed toward lower topographic elevations. The watertable configuration indicates recharge to the shallow groundwater flow system from sloughs sporadically distributed over the site.

4.3 Hydraulic Conductivity of Near-Surface Sediments

The hydraulic conductivity (permeability) of geologic materials was calculated from data obtained by single-well response tests. A total of 38 tests were completed, with the resultant conductivity values ranging from 1.2×10^{-4} to 8.0×10^{-8} cm/s. The distribution of conductivity values by order of magnitude is summarized as follows:

Order	No. of Values
10^{-4}	1
10^{-5}	5
10^{-6}	14
10^{-7}	16
10^{-8}	2

Conductivity values for individual piezometers are listed in Table 4.1. As indicated in the Table, 13 piezometers were not tested as these had not attained stabilized levels prior to testing; in view of slow recovery rates the hydraulic conductivity of materials within which the tips are completed is expected to lie in the range of 10^{-7} to 10^{-8} cm/s. Hydraulic conductivity values in the order of 10^{-4} and 10^{-5} cm/s are high, indicating relatively permeable materials at these locations. Piezometers 9E and 14C are completed in shale, and the high conductivity values suggest the tips have intersected fractures, Piezometers 22N and 22C are also completed in shale, but the seals are suspect in these owing to completion difficulties. Of the 38 test results and estimated conductivities of an additional 13 locations, only three results indicate the presence of fractures and it is considered that the incidence of fractured materials to a depth of 18 metres beneath the Consort Site is low.

Table 4.1: Hydraulic Conductivity of Geologic Materials

Piez. No.	Depth (m)	Material	Hydraulic Conduct. (cm/s)
1E	18.85	Shale	8.0×10^{-8}
1C	12.26	Till	1.5×10^{-5}
1W	6.20	Till	Dry
2E	18.43	Shale	Dry
2C	12.41	Till	Dry
2W	6.38	Till	Dry
3E	18.62	Shale	4.8×10^{-6}
3C	12.47	Till	8.0×10^{-8}
3W	6.34	Till	Dry
4E	9.60	Till/Sand	4.8×10^{-6}
4C	9.71	Sand/Till	3.8×10^{-6}
4W	6.14	Till	Dry
5E	18.21	Till	1.8×10^{-7}
5C	12.17	Till	2.2×10^{-7}
5W	6.18	Till	Dry
6E	18.35	Shale	Unstable
6C	11.69	Shale	2.3 s 10^{-6}
6W	5.77	Till	Dry
7E	17.58	Shale	Unstable
7C	12.03	Shale	Unstable
7W	6.20	Till	Dry
8E	18.05	Shale	1.0×10^{-7}
8C	12.14	Shale	1.6×10^{-7}
8W	6.09	Till	Dry
9E	18.41	Shale	1.2×10^{-4}
9C	12.47	Till	Unstable
9W	6.12	Till	Dry
10E	18.44	Till	2.5×10^{-6}
10C	11.12	Till	7.3×10^{-7}
10W	6.30	Till	9.0×10^{-7}

Table 4.1: Hydraulic Conductivity of Geologic Materials - Continued

Piez. No.	Depth (m)	Material	Hydraulic Conduct. (cm/s)
11E	17.73	Shale	7.0×10^{-7}
11C	11.66	Shale	9.0×10^{-7}
11W	5.74	Till	Dry
12E	18.31	Shale	1.6×10^{-7}
12C	12.08	Shale	1.9×10^{-7}
12W	6.27	Till	Dry
13E	18.26	Shale	2.0×10^{-6}
13C	12.16	Shale	2.5×10^{-7}
13W	6.11	Till	Dry
14E	18.76	Shale	2.1×10^{-6}
14C	12.33	Shale	1.2×10^{-5}
14W	6.30	Till	Dry
15E	18.49	Shale	Dry
15C	12.79	Till	2.7×10^{-7}
15W	6.14	Till	Dry
16E	18.54	Shale	8.0×10^{-7}
16C	12.17	Shale	2.5×10^{-6}
16W	6.17	Till	Unstable
17E	18.50	Shale	Unstable
17C	12.18	Shale	2.9×10^{-7}
17W	6.13	Till	Dry
18E	18.42	Shale	Unstable
18C	12.18	Shale	1.5×10^{-6}
18W	6.26	Till	Dry
19N	18.55	Shale	Unstable
19C	12.25	Shale	2.2×10^{-6}
19S	6.30	Till	Dry
20E	18.41	Shale	Unstable
20C	12.21	Shale	5.2×10^{-7}
20W	6.22	Till	Dry

Table 4.1: Hydraulic Conductivity of Geologic Materials - Continued

Piez. No.	Depth (m)	Material	Hydraulic Conduct. (cm/s)
21E	18.59	Shale	1.3×10^{-6}
21C	11.79	Shale	6.1×10^{-6}
21W	6.25	Till	Dry
22N	13.26	Shale/Sand	2.2×10^{-5}
22C	11.39	Shale/Sand	2.5×10^{-5}
22S	8.71	Shale	3.5×10^{-6}
22SS	6.12	Till	Unstable
23N	19.18	Shale	5.0×10^{-7}
23C	12.25	Till	4.1×10^{-7}
23S	7.02	Sand	Dry
23SS	5.44	Till	Dry
24N	17.99	Shale	Unstable
24C	12.18	Shale	9.5×10^{-7}
24S	6.00	Till	Dry
25N	17.70	Shale	Unstable
25C	11.25	Shale	Unstable
25S	5.21	Till	Dry

4.4 Groundwater Velocity

The mean linear velocity of groundwater moving through a porous medium is governed by the applied hydraulic gradient (dh/dl), hydraulic conductivity (K) and porosity (N) as indicated in the following relationship:

$$V = \frac{K \frac{dh}{dT}}{N} \qquad \text{(Equation 4.1)}$$

From an equipotential map of the watertable surface, the hydraulic gradient ranges from 4.4×10^{-3} to 3.3×10^{-2}. Using conductivities in the range of 10^{-6} to 10^{-7} cm/s, and assuming an effective porosity of 10% a velocity matrix can be constructed to illustrate a general range in anticipated groundwater velocity:

$K =$	10^{-7}	10^{-6}
$\frac{dh}{dl}$	Minimum Velocity	
4.4×10^{-3}	4.4×10^{-9} cm/s	4.4×10^{-8} cm/s
		Maximum Velocity
3.3×10^{-2}	3.3×10^{-8} cm/s	3.3×10^{-7} cm/s

Given the range in governing parameters, the range in groundwater velocity might be expected to range from 0.1 to 10 cm/year.

The presence of fractures within either till or shale is suggested by a small number of conductivities in the orders of 10^{-4} and 10^{-5} cm/s. Groundwater velocities would be considerably greater than those presented above should groundwater flow be governed by an extensive interconnected system of fractures. The hydraulic conductivity values obtained to date do not support the presence of widespread interconnected fractures beneath the Consort Site.

4.5 Vertical Component of Groundwater Flow

Comparison of piezometric surface maps at two depths indicate that slight downward (recharge) gradients exist over most of the Consort Site. Apparent recharge gradients are commonly encountered in near-surface sediments of low permeability, as the intergranular hydraulic conductivity in the vertical direction of such sediments is usually

less than the horizontal direction. The conductivity contrasts in the two directions retard the downward movement of groundwater, resulting in a perched watertable and apparent recharge gradients. Hydrogeologic cross-sections for the Consort Site illustrate perched groundwater conditions and also indicate that the predominant direction of groundwater flow is approximately horizontal, parallel to surface topography.

4.6 Groundwater Resources

The aquifer potential of sandstones situated between 22 and 90 metres below surface was evaluated by conducting brief air-lift tests from two 90 metre deep test holes. The tests yielded 10 and 27 L/min respectively. The groundwater is of reasonably good quality considering the marine origin of the Bearpaw Formation; the water is a sodium sulfate type with a total dissolved solids of 1650 mg/L. While suitable for domestic use, the yields and quality are not suitable to the requirements of a waste treatment facility.

The Bearpaw Formation is reportedly 152 metres thick in the immediate area of the Consort Site. The underlying Oldman Formation is in the order of 80 metres thick and reportedly contains sandstone aquifers which may be capable of yielding fresh water at rates of 25-115 L/min. In view of the thick Bearpaw sequence, potential aquifers in the Oldman Formation are considerably beyond the influence of contamination from waste treatment facilities on the surface.

4.7 Potential for Groundwater Contamination

The potential for affecting groundwater quality in the vicinity of a waste management site is governed by a number of factors, including:

1) physical state and reactivity of materials requiring land disposal,
2) hydraulic conductivity (permeability) of geologic materials cradling the land-based disposal area, and
3) the potential for leachate generation.

The intent of providing a special waste management facility is to allow for treatment and proper disposal of waste materials. Residues from the treatment process would be transferred to a land-based disposal component, and would include non-reactive, inert, or chemically fixed materials. In the absence of free-form waste products, contaminants would not be available for mobilization in soil or groundwater systems.

The geologic setting is equally important in restricting movement of contaminants in the subsurface. The objective of a hydrogeologic investigation is to locate a site where contaminant transport via the groundwater system would be negligible or severely restricted. As indicated in earlier sections the Consort Site provides such natural barriers to contaminant movement, and engineering design of treatment and land disposal components would further enhance the natural hydrogeologic features of the site.

In terms of leachate generation the semi-arid climate of the Consort area, combined with engineering design measures to restrict infiltration of precipitation will reduce the potential for leachate generation. Should leachate be generated, however, it would consist only of potentially mobile components dissolved from the non-reactive waste forms and its movement in any case would be restricted by the natural barriers presented by the site geology.

Given a properly designed and operated waste treatment facility and the natural geologic and climatic setting of the Consort Site, the potential for affecting groundwater quality is negligible.

SECTION FIVE

SUMMARY AND CONCLUSIONS

Interpretations of test drilling data within Section 17 and N1/2 8-34-6-W4 indicate the presence of a highly variable glacial drift thickness overlying bedrock of the Cretaceous-age, marine Bearpaw Formation. The drift is primarily clay loam-textured glacial till with minor bands of glaciolacustrine and glaciofluvial materials incorporated within. The drift contains relatively large quantities of thrust, slumped or rafted bedrock materials in some areas, primarily in the central portion of N1/2 17.

The Consort Site, legally described as SE 17-34-6-W6, was selected as the most suitable quarter section for development of a waste management facility. The quarter is situated east of the preglacial till valley and most of the valley is infilled with minor amounts of glaciofluvial, glaciolacustrine and incorporated bedrock materials. There are no aquifers within the glacial drift sequence, although glaciofluvial sands and gravels underlying the western boundary may produce limited quantities of groundwater.

Bedrock materials consist of soft, unconsolidated sandstones, shales and minor amounts of siltstone. The bedrock was investigated to a depth of 90 m (including drift thickness) and, based on fossil fragments and mineralogy, the materials from bedrock surface to the depth of investigation are of the marine-origin Bearpaw Formation. The upper portion of the Bearpaw sequence consists of shale (clayey silt); the uppermost sandstone unit lies at least 18 m, and likely closer to 22 m, below present land surface. The sequence from 22 to 90 m below surface consists of interbedded sandstone and shale interrupted by bentonite and indurated siliceous horizons.

Groundwater conditions within 18 m of surface were investigated by installation of 25 piezometer nests. The watertable lies everywhere at depths ranging from five to eight metres below surface and groundwater flow within the aquitard system of deposits is directed primarily west and southwest. The hydraulic conductivity of materials within the depth of investigation is primarily in the order of 10^{-6} to 10^{-7} cm/s. Conservatively high estimates place groundwater velocity within 18 m of surface at 10 cm/year; a more realistic velocity estimate is in the order of 10 cm/decade.

Single-well response tests indicate the presence of localized fractures beneath the zone of saturation. The incidence of fracturing, as indicated by test results, is low; it is considered that groundwater flow within 18 m of surface is governed by intergranular rather than fracture porosity.

Exploration for groundwater aquifers was conducted to a depth of 90 m. Sandstone aquifers are present beneath the Consort Site at a depth of 23 m. Air-lift tests at two locations on site recovered 10 and 27 L/min respectively, of reasonably good quality groundwater. The tests suggest that available yields will satisfy domestic requirements, but will not meet the demands of industrial development.

Comparison of piezometric surfaces at two levels indicate that slight recharge gradients exist over most of the Consort Site. Available data indicate a minimal vertical flow component in comparison to the horizontal, however, and that the potential for groundwater flow within the aquitard system of deposits extending to a depth of 18 metres is predominantly horizontal. Given this hydrologic setting, recharge to underlying aquifers will not occur through the Consort Site.

SECTION SIX

RECOMMENDATIONS

Based on the hydrogeologic setting as identified in the present investigation, the Consort Site is well-suited to development of a special waste management facility. The geologic deposits within 18 m of surface are uniformly fine-grained and exhibit favourably low intergranular hydraulic conductivities. Should spills, accidents or other unscheduled events occur resulting in toxic or reactive substances being released at the surface, such substances will remain in close proximity to the point of release while recovery mechanisms are implemented.

The watertable beneath most of the Consort Site is at a depth sufficient to preclude interference with design and operation of a special waste management facility. Groundwater levels of five to eight metres below surface are well-suited to excavation of landfill trenches, liner placement and maintenance, and landfill operation.

Fractures detected in the subsurface require engineering measures to ensure the integrity of containment features such as lagoons and landfill excavations. Fractures are commonplace in Alberta, both in glacial and bedrock deposits, and are routinely dealt with in engineering designs. It is recommended that an engineering firm be consulted regarding the type of liners or construction practices required to eliminate the possibility of reactive or toxic substances from migrating via fracture systems beyond the engineered boundaries of the facility.

Consideration should be given to placement of a monitoring system beneath areas designated for storage or final disposal of treated materials.

The monitoring system could consist of direct-sampling techniques or chemically sensitive sensors, but should be placed directly beneath designated areas during construction. Groundwater monitoring wells should be included in the design, but these should not be considered reliable for the early detection of contaminant release to the subsurface.

POOR

QUALITY

ORIGINAL